Climate Trends in the Gulf of Alaska and the Bering Sea, 1950-1997: Ecosystem Implications

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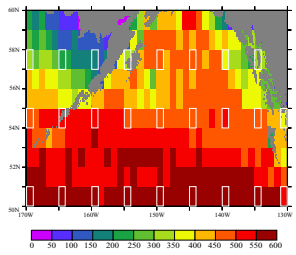
Western and eastern Gulf of Alaska have experienced different climate dynamics over past 50 years, implying different responses of eastern and western Steller sea lion populations to climate variability

OBJECTIVES

We are exploring climate variability in the Gulf of Alaska and the eastern Bering Sea from 1950 to 1997, based on *in situ* surface oceanic and atmospheric observations. Our objectives are to:

- Identify long-term trends in surface oceanic and atmospheric variables.
- Identify periods of abrupt climate change.
- Describe the forcing mechanisms and spatial patterns of the variability.
- Speculate on the impact of this variability on local ecosystem structure, particularly the impact on Steller sea lions through bottom-up forcing.

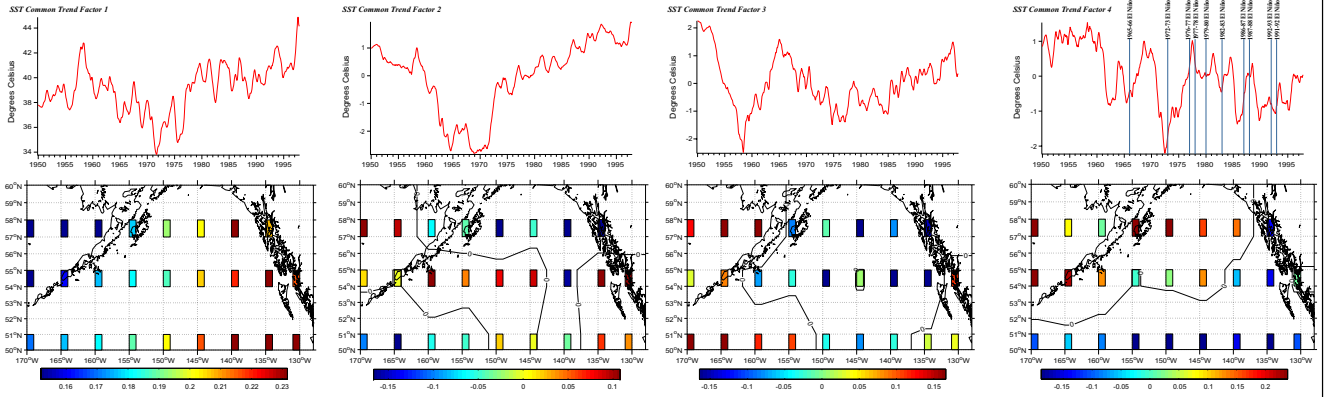
Number of SST Observations COADS, 1950-1997



Observations and Methodology

Number of months of COADS SST observations in each 1° box over the period 1950-97 (*above right*); white outlines indicate boxes used in this analysis. COADS winds also analyzed for same boxes. State-space models were used to separate non-linear trends from seasonal trends in the monthly mean time series. Subspace identification techniques were used to estimate common climate trends of all series.

Time Series and Distribution of Loadings for Four Components of the SST Common Trend



Colors in One-Degree Boxes Show Factor Loadings at Each Location; Contours show zero crossings

SST 1

- Loadings increase from west to east.
- From 1972 onward, region experienced a warming trend.
- The warming trend accelerated in 1976.

SST 2

- Component 2 accentuates component 1, especially in central Gulf of Alaska and eastern Bering Sea.
- Areas with positive loadings experienced strong warming after 1972.

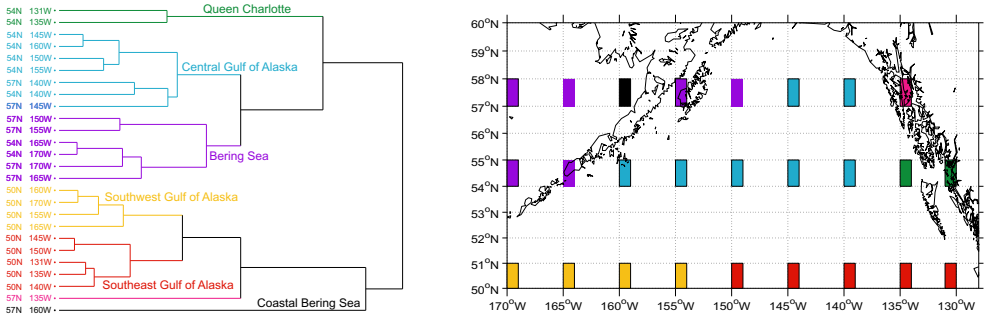
SST 3

- Component 3 shows strong warming in eastern Gulf of Alaska during 1957-58 El Niño event.
- Eastern Bering Sea cooled during 1957-58 event.

SST 4

- Component 4 captures much of the interannual variability in SST.
- Fluctuations reflect El Niño events, except for 1957-58 event, which is captured in component 3.
- Impacts of El Niño events strongest in coastal BC and West Wind Drift

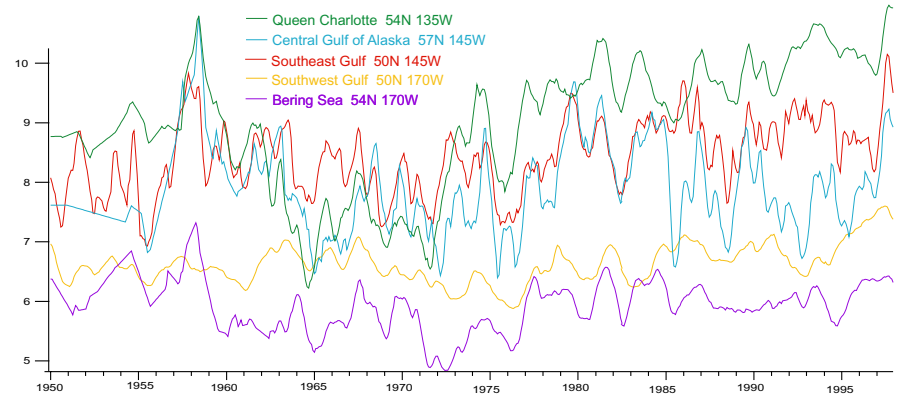
Cluster Analysis of SST Factor Loadings for Components 2-4



Clusters

SST loadings from components 2-4 form five geographical clusters. Bering Sea (*purple*) and central Gulf of Alaska (*blue*) group together strongly, and couple more weakly with Queen Charlotte Islands (*green*). Southeastern Gulf of Alaska (*red*) and southwestern Gulf of Alaska (*yellow*) form a separate pair of clusters.

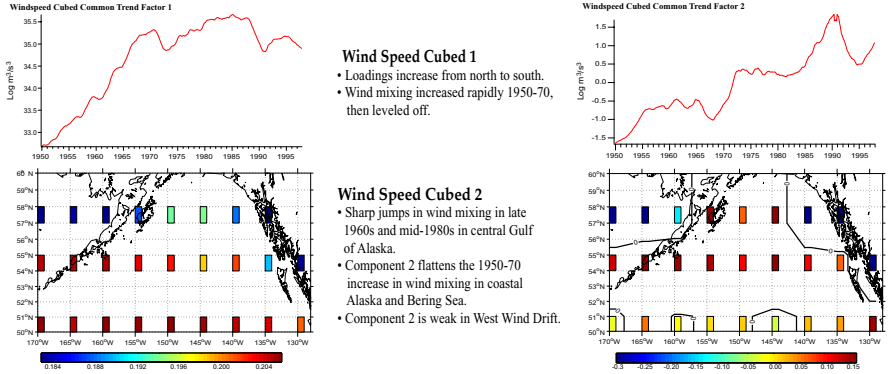
Time Series of SST at Five Representative Locations



Time Series

Representative SST time series for each of the five geographical clusters. Dynamics of component and cluster analyses are evident in the individual series.

The Time Series and Distribution of Loadings for Two Components of the Wind Speed Cubed Common Trend



Wind Speed Cubed 1

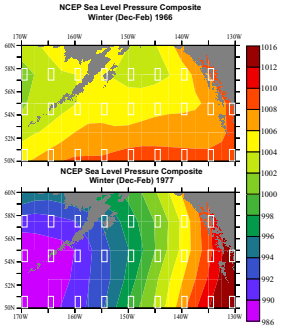
- Loadings increase from north to south.
- Wind mixing increased rapidly 1950-70, then leveled off.

Wind Speed Cubed 2

- Sharp jumps in wind mixing in late 1960s and mid-1980s in central Gulf of Alaska.
- Component 2 flattens the 1950-70 increase in wind mixing in coastal Alaska and Bering Sea.
- Component 2 is weak in West Wind Drift.

Colors in One-Degree Boxes Show Factor Loadings at Each Location; Contours show zero crossings.

SHIFT IN ALEUTIAN LOW FROM 1966 TO 1977



Pressures

Winter SLP composites (*shown at right*) reveal strengthening and eastward shift of Aleutian Low. Trends in wind speed cubed and north-south wind stress (*not shown*) are consistent with this shift. Warming in eastern Gulf of Alaska accompanied the change in atmospheric forcing.

CONCLUSIONS

- SST clusters into five distinct regions.
- Warming trend began in early 1970s in most areas, and accelerated in some areas in 1976.
- Effects of the 1957-58 El Niño strongest in eastern Gulf of Alaska.
- Other El Niños have largest impact in coastal BC and the West Wind Drift.
- Evidence suggests that changes in SST correspond to shifts in large-scale atmospheric forcing.
- Western and eastern Gulf of Alaska have experienced different climate dynamics.
- Regional differences in climate variability may affect trends in eastern and western Steller sea lion populations differently.

FUTURE WORK

- **Examine temporal changes in seasonal components of these environmental parameters.**
- **Observed climate trends will be used to force regional biological models and to explore bottom-up forcing of fish stocks and marine mammals in Alaskan waters.**

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